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Education Department Bulletin

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New York State Museum

JOHN M. CLARKE, Director

Museum bulletin 126

GEOLOGY OF THE REMSEN QUADRANGLE

INCLUDING TRENTON FALLS AND VICINITY IN ONEIDA AND HERKIMER COUNTIES

BY

W. J. MILLER

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New York State Education Department
Science Division, July 2, 1908

Hon. Andrew S. Draper LL.D.
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SIR: I have the honor to communicate herewith for publication as a bulletin of the State Museum, a report on the Geology of the Remsen Quadrangle, including the Vicinity of Trenton Falls, N. Y., accompanied by a geologic map of the region. The work has been prepared by Prof. W. J. Miller of the staff of this division.

Very respectfully
JOHN M. CLARKE
Director

State of New York
Education Department
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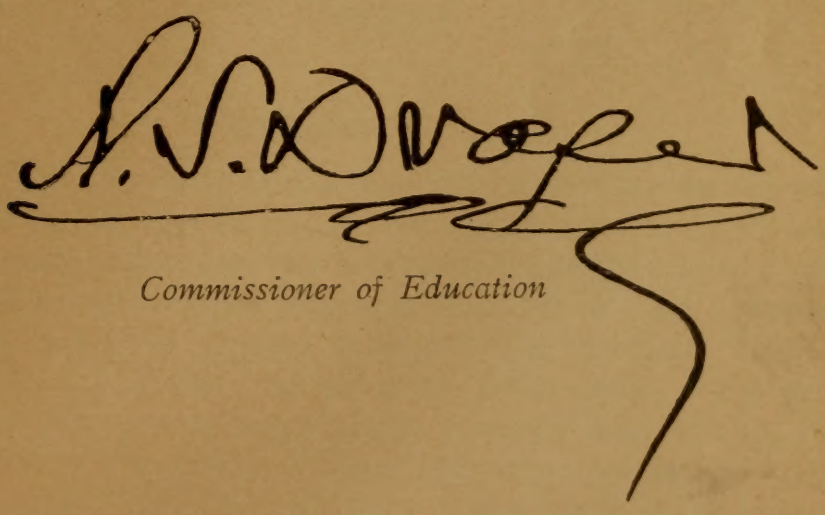
Approved for publication this 3d day of July 1908



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GEOLOGY OF THE REMSEN QUADRANGLE

INCLUDING TRENTON FALLS AND VICINITY IN ONEIDA AND HERKIMER COUNTIES

BY

W. J. MILLER

INTRODUCTION

The territory described in this report is covered by the Remsen quadrangle of the United States Geological Survey. The map covers $\frac{1}{16}$ square degree and lies between latitude lines 43° 15′ and 43° 30′ north, and between longitude lines 75° and 75° 15′ west. The region, partly in Oneida and partly in Herkimer county, lies along the southwestern border of the Adirondacks. The map represents nearly 216 square miles of territory and includes the type locality of the classic Trenton limestone formation. The gorge at Trenton Falls has long been famous both for its scenic beauty and because of the interesting geological section there shown.

The whole territory was formerly heavily forested, but at the present time the woods are confined almost entirely to the northeastern part and even there much of the timber is of second growth. A number of sawmills are now in operation as at Nichol's Mill,

Forestport, Remsen, Bardwell Mill, one on Little Black creek, Northwood, Grant, and a large pulp mill at Hinckley, within the territory. The southwestern half of the region is devoted primarily to agriculture and dairying.

GENERAL GEOLOGIC FEATURES

Under this heading it is proposed to briefly outline the geologic history of the whole Adirondack region so that the detailed study presented in this report may be made more intelligible to the reader. This outline is largely based on the admirable treatises of Prof. H. P. Cushing.

So far as known the oldest rocks of the Adirondacks are those of Grenville (Precambric) age. They are sedimentary rocks, originally shales, sandstones and limestones, which have been highly metamorphosed into gneisses and crystalline limestone. These rocks are of unknown though great thickness, and are widely scattered throughout the Adirondacks; thus showing that the whole region was under water at the time of their deposition.

After the deposition of the Grenville sediments the region was raised above the ocean level and the rocks began to decompose and suffer erosion. Either just before, during or after the uplift, great masses of igneous rocks were intruded. The Grenville rocks were for the most part engulfed by the intrusion so that only occasional patches of them were left intact.

After the igneous activity the rocks became thoroughly metamorphosed by being squeezed, highly folded and converted into gneisses. Such changes can take place only at great depths (several thousand feet) and hence we are led to the belief that a vast erosion of the original land masses must have taken place. This in turn signifies that the land masses must have remained above sea level for an immense length of time.

At or toward the close of this long period of erosion, igneous activity of a minor character took place. The basic igneous rocks erupted at this time are especially well shown in the northeastern Adirondacks where they were squeezed up between joint planes in the older rocks. That these rocks are much younger than the igneous rocks first mentioned is clearly shown by their mode of occurrence and their general lack of metamorphism.

At the conclusion of the erosion period the region of the Adirondacks was nearer the sea level and of slighter relief than at present. Then the whole region began to sink slowly, allowing the sea to encroach upon the land until only an island was left or probably

even until the whole region was under water. During the subsidence, deposition of Paleozoic sediments went on, one layer above another, the younger deposits overlapping each other and encroaching upon the sinking land surface. Since the subsidence was not entirely uniform on all sides certain local variations in deposition occurred.

The first of the deposits to form upon the sinking floor was the Potsdam (Cambric) sandstone now found exposed nearly everywhere except along the southwest border. After this the sediments changed in character and the limestones of the Beekmantown (Lower Siluric) were laid down. Then followed the deposition of the highly fossiliferous Trenton (Lower Siluric) limestones, including the Lowville and the Black River limestones. The fairly clear waters full of animal life then gave way to the muddy waters of the Utica, when the Utica shales (Lower Siluric) were deposited. At this time the Adirondack region was probably all under water. Next came an uplift on the east and northeast where deposition ceased. On the south and southwest, however, deposition continued and the successive formations of the Siluric and Devonic above the Utica shale were laid down. These Paleozoic formations may now be seen as one passes from the Adirondacks southward to the southern border of the State.

The last period of igneous activity in the Adirondacks occurred some time after the close of the Lower Siluric. This activity was of minor extent and showed itself in the form of dikes.

At some time after the deposition of the Utica shale the rocks, especially along the southern border, were deformed chiefly by faulting. A series of these faults extends across the Mohawk valley, a small one being present within the limits of the Remsen quadrangle. The southern Adirondacks, including the Trenton Falls district, have been subjected to erosion for a vast length of time, certainly since the close of the Paleozoic and more than likely since the Devonic. During this great lapse of time a large amount of material has been removed. Doubtless the whole Remsen quadrangle was at one time covered by the Utica shales, which have all been removed except along the western side.

The superficial deposits, such as sands, gravels and clays, which are so common over the Trenton Falls district were deposited either directly or indirectly by the great ice sheet of the Glacial age. From the geological standpoint this ice sheet was present only quite recently and covered most of New York State.

TOPOGRAPHY AND DRAINAGE

The region of the Remsen quadrangle presents a very ancient topography since it has been above water and subjected to erosion at least since the close of the Paleozoic era. The major topographic features are the result of this long continued wear, but the whole region has been thoroughly glaciated, and the detailed surface configuration has often been quite appreciably affected by the accumulation of glacial drift.

The region is a characteristically hilly one, with the greatest difference in altitude above sea level being from a little over 700 feet, where West Canada creek leaves the map, to nearly 1900 feet in the extreme northeastern portion, where several points reach to and above the 1800 foot level.

Extending northeastward from a line passing through Forestport and Grant, to the highlands just mentioned, there is a gradual upward slope which continues into the Adirondacks. In fact these highlands may be looked upon as foothills of the Adirondacks. Minor highlands occur in the west-central part of the district where the culminating point is Starr hill over 1780 feet above sea level. From Starr hill southward the general slope is towards the Mohawk river. As Professor Brigham has said, the magnificient view from the top of this hill strongly impresses one with the greatness of the Mohawk valley as a topographic feature.

The country lying between the two highland areas is mostly drift covered and shows usual elevations of from 1100 to 1400 feet. The central and southeastern parts of the quadrangle are deeply drift covered, the drift ranging from 100 to 300 or 400 feet deep and the hill tops ranging from 1300 to 1500 feet above the sea level.

The principal streams are Black river and West Canada creek, the latter stream being the chief tributary of the upper Mohawk river. These two streams present some of the most interesting drainage features of the southwestern Adirondacks. They have their sources close together in the Adirondacks and they flow southwestward approximately parallel for 30 or 40 miles to within the map limits where a striking divergence occurs. Black river turns northwestward or at right angles to its upper course, while West Canada creek turns southeastward and also at right angles to its upper course. At one point within the map limits the two streams are but little more than 4 miles apart. Black river continues northwestward to Carthage and thence westward into Lake Ontario; while West Canada creek continues southeastward and southward

to empty into the Mohawk river at Herkimer. Thus Black river forms a part of the St Lawrence drainage system while West Canada creek forms a part of the Mohawk-Hudson system.

Another striking but well known feature of Black river is the fact that it follows close to the Paleozoic-Precambric contact for many miles. Doubtless the character of the Paleozoic rocks (mostly limestones) has had much to do with the determination of its course along this line.

The main tributaries of Black river within the map limits are Big and Little Woodhull creeks on the north and Little Black creek on the south. The main branch of West Canada creek on the north is Town Line (Cincinnati) creek and on the south Black creek.

Certain other topographic and drainage features are discussed in the following pages.

ROCKS OF THE REGION

The rocks of the region include Precambric crystallines and Paleozoic sedimentaries. Each of these rock classes occupies approximately one half the area and they are separated on the geologic map by a line running southeast and northwest. The Precambric rocks represent a portion of the great Adirondack crystalline mass along its southwestern border. The Paleozoic rocks are of Lower Siluric age and overlap on the crystallines.

Precambric rocks

Grenville gneiss. Rocks of Grenville age comprise a series of highly metamorphosed sediments and they occur in but one well defined area within the map limits. This area, nearly triangular in shape, covers several square miles and extends from Enos south and southwestward. The best exposures are in the vicinity of Enos where for about a mile downstream Black river has cut a gorge through the Grenville rocks which are finely exposed. Another large outcrop may be seen where a road crosses Little Black creek about a mile and a half from its mouth. Grenville rocks have been found in many other parts of the region but they are so thoroughly involved with syenitic masses that they can not be separately shown on the geologic map.

Where the Grenville rocks are found in considerable areas in the northwestern Adirondacks, crystalline limestones are commonly associated with them, and the limestone proves the original sedimentary character of the formation. These characteristic crystalline limestones have not been found in the region here described.

They have recently been found in the adjoining Little Falls district.[1] Cushing notes the presence of limestone boulders near the northern edge of the Little Falls sheet which makes it probable that the limestone occurs on the Wilmurt sheet which lies east of the Remsen sheet. Another occurrence is at Fourth lake of the Fulton chain.[2] Thus it appears that the Grenville limestones are only poorly developed along the southwestern border of the Adirondacks.

The strongest evidence for the original sedimentary character of the Grenville rocks within the Remsen quadrangle is the fact that layers of very different composition and color are in sharp contact and often show rapid alternations. Such phenomena are well exhibited in the Black river gorge at Enos, where the rock layers stand in almost vertical position and strike n. 70° e. Near the old mill there are many layers of very light color made up almost entirely of feldspar and quartz. These rocks must originally have been beds of feldspathic sandstone and it appears probable that the present banding corresponds closely to the former stratification of the sandstone. These light colored layers are clearly interbedded with dark gray and almost black feldspathic and hornblendic or biotitic rocks. Although some of these darker rocks appear to be of igneous origin and closely associated with the Grenville, nevertheless many of them are more than likely of sedimentary origin and were probably originally shales.

Another strong evidence for the sedimentary origin of the Grenville rocks is the presence of graphite in them. Graphite flakes often a millimeter or more across and exhibiting a shiny metallic luster are very common in certain of the lighter gray layers near the mill at Enos. More rarely the graphite occurs in the darker layers. It is difficult to account for the graphite except on the basis of organic origin. Thus we may argue that the original sandstones and shales were more or less carbonaceous and during the process of metamorphism the organic matter was changed and crystallized into graphite.

Another mineral suggesting a sedimentary origin which is often found in light red crystals, especially in the darker layers, is garnet. Garnets are rather more frequently present in metamorphic rocks of sedimentary origin and their presence here, often in abundance, seems to suggest such an origin for the Grenville.

[1] Professor Cushing has called the writer's attention to the discovery of this limestone by D. H. Newland. *See* N. Y. State Mus. Bul. 119. p. 143.

[2] Smyth, C. H. jr. Crystalline Rocks of the Western Adirondacks. N. Y. State Mus. 51st An. Rep't, v. 2. 1897.

The Grenville presents many different facies and below follows a description of the principal types which are represented by different layers. A common type is distinctly marked by alternating light and dark bands, the light bands consisting mostly of plagioclase feldspar and quartz, while the dark bands are chiefly biotite mica and hornblende together with garnet.

Another type is of light gray to greenish gray color and rather fine grained. The principal constituent is augite with a fair amount of anorthoclase and quartz together with several per cent of graphite.

A third type shows a very thin banding, is almost white and is made up chiefly of plagioclase (oligoclase) feldspar with some quartz.

A fourth type is fine to medium, light colored, and is made up of about 75% of anorthoclase, 20% of quartz and 5% of biotite, magnetite and garnet.

A fifth type is dark gray micaceous, consisting of about 60% of oligoclase, 25% of biotite mica, 10% of quartz and a little magnetite and hornblende.

A sixth type, which is rare, consists mostly of enstatite (or bronzite) with some quartz.

A seventh type contains much sillimanite accompanied by anorthoclase, quartz, magnetite and biotite. The sillimanite occurs in long glistening needles visible to the naked eye. This type was observed only near Forestport, where Grenville and syenite rocks are closely associated.

Accompanying the above described Grenville rocks and interbanded with them are certain rock types which are presumably igneous in origin. One of these rock types is gray, medium grained and consists of about 50% of feldspar — anorthoclase and oligoclase — 25 to 30% of quartz, varying amounts of hornblende, hypersthene, biotite mica, magnetite, and a little pyrite, apatite and zircon. Found alone in the field it would be impossible to distinguish this rock from the typical syenite below described.

Another of these rocks thought to be igneous in origin is black, fine grained and highly banded. It consists chiefly of hornblende (50 to 60%) associated with plagioclase feldspar (30 to 40%) which ranges from oligoclase to labradorite and about 5% of magnetite. According to the composition the original rock would have been a gabbro. These apparently igneous rocks can in no case be represented as separate areas upon the map.

Since the rocks of the Grenville series have been so profoundly

changed by metamorphism, it is possible that the rocks above referred to as igneous may not be igneous at all, while others not referred to as igneous may in reality be igneous. Nevertheless most of the rocks of the series appear to be of undoubtable sedimentary origin.

Syenite gneiss. A considerable portion of the region mapped as Precambric is made up of a rock which shows every indication of being truly igneous in origin. Also its areal distribution and relation to the Grenville rocks [*see* below] clearly indicate that it is intrusive in character. Study shows this rock to be a syenite gneiss. It is from fine to medium grained and shows the typical granitoid texture. The weathered surface of all exposures is of a light brown color, while the real color of the fresh rock is greenish gray. Because of the depth of the weathering the fresh rock is usually difficult to obtain. As compared with the other Precambric rocks this syenite presents a remarkably uniform structure and composition throughout. Near the contact with the adjacent syenite-Grenville complex (below described) the rock is usually somewhat finer grained and not so typical in character.

Of the two areas mapped, the larger is very irregular in shape and occupies much of the northeastern portion of the district. This mass is mostly heavily wooded and the exposures are often few in number and unsatisfactory. However, many large exposures have been found, especially in the vicinity of Northwood, North Wilmurt, Reeds Mill and on the Little Black creek near the county line. The smaller area lies in the town of Forestport extending northeastward from Forestport station for several miles and on either side of the railroad. Although much of the area is sand covered, excellent exposures may be seen at Woodhull, Meekerville and in the stream beds southeast, west and southwest of Anos Siding.

The syenite clearly exhibits a gneissic structure although it is not distinctly banded. The concentration of dark colored minerals such as biotite and hornblende along certain lines serves to accentuate the gneissic structure. These lines are wavy and as a rule do not extend far without interruption. All the outcrops show the gneissic structure although it is not always evident in the hand specimen.

Under the microscope the mineralogical composition is shown to be feldspar — including anorthoclase, microperthite, and acid plagioclase — quartz, hornblende, biotite, augite, enstatite (or bronzite), magnetite, apatite, zircon, titanite.

The most abundant constitutent is feldspar, which shows a range of from 65 to 80%, while the average amount present is a little over 70%. Of the feldspars, the anorthoclase and the microperthite are most common, sometimes the one and sometimes the other predominating. The anorthoclase is recognized by the very minute multiple (microcline) twinning bands, often indistinct but presenting a sort of moiré effect. Occasionally the multiple twinning is more distinct and then the feldspar may indeed be microcline. Microperthitic intergrowths especially in the larger feldspars are often beautifully shown. Acid plagioclase is a constant constitutent of the syenite, though always subordinate in amount. It is mostly oligoclase with low extinction angles although at times some of it ranges over to andesine.

The second most abundant mineral is quartz, which makes up from 10 to 25% of the rock or on the average a little over 15%. The quartz grains vary greatly in shape and size and sometimes they are larger than the feldspars. The quartz percentage is often high enough to make the rock a quartz syenite at times approaching granite. The quartz, as well as the feldspar, in nearly all cases appears to have been entirely recrystallized.

Among the dark colored minerals hornblende is a very constant constituent. It appears to be common hornblende with its characteristic cleavage and pleochroism from light to dark green. Often it may be seen partly or completely changed to chlorite. The maximum amount of hornblende present is about 10 or 12%.

Biotite mica is also always present in scattering flakes, never making up more than 5% of the rock.

The pyroxenes — augite and enstatite (or bronzite) are frequently present but always in small quantity.

Magnetite — never above 5% — is a constant constitutent. The development of leucoxene borders around the magnetite may often be seen.

Many very small prismatic crystals of apatite, generally as inclusions in feldspar or quartz, occur scattered through the rock.

Besides the minerals mentioned occasional small crystals of zircon and titanite are present. All of the dark colored constituents may occur in the same specimen but together they never make up more than 20% of the rock.

Syenite-Grenville complex. The rocks here described occupy approximately one half of the Precambric area. Rocks of many different kinds have been included under this head and, both because of the small scale of the map and the scarcity of exposures, it has not been possible to separate these rocks upon the geological map.

The term "Syenite-Grenville complex" is used by the writer because the rocks, for the most part at least, appear to be a rather intricate mixture of the syenitic and Grenville rocks already described. Especially in certain of the large exposures, as in the vicinity of Forestport, Myers hill, north of Enos, near the northern limit of the map along the railroad, etc., rocks which if present alone would undoubtedly be classed with the syenite are closely associated with others which show characteristic features of the Grenville. The two rocks show great variation in amount although the syenites generally predominate. In large exposures in the field the rocks of the complex may be easily distinguished from the typical Grenville because the bands are not so well developed and straight, and also because of the basic inclusions. They differ from the pure syenite because of a better development of the gneissic structure and a decided lack of homogeneity.

There is strong evidence that the Grenville sediments are the older and that the syenite has been intruded into them. One argument in favor of this view is the fact that the two rocks are so thoroughly involved and that neither may be said to rest upon the other. But the strongest argument lies in the fact that portions of the rocks mapped as Grenville may be seen as actual inclusions within the syenite. Among the localities where such inclusions occur are: at the bridge near the mouth of Little Black creek; 2 miles east of Enos on the south side of Ash ridge; near Forestport; where the railroad crosses Big Woodhull creek; and to the south of Myers hill. Thus the syenite appears to be intrusive into and therefore younger than the Grenville. Certain results obtained by C. H. Smyth jr[1] in the western Adirondacks seem to point to the same conclusion.

Because of the great variety of rocks mapped under this heading and the frequent gradations of the different types into each other it is very difficult clearly to describe them. In general it may be said that nearly all of the minerals occurring in either the Grenville or the syenite have been found in this complex and also that the microperthite is lacking while the anorthoclase, plagioclase and quartz as well as the dark colored minerals show all sorts of variations in relative abundance.

The most common type is a rock of syenitic character, which in the hand specimen very closely resembles the homogeneous syenite already described. Although under the microscope the rock shows a general lack of microperthite and a greater richness

[1] N. Y. State Mus. 51st An. Rep't, v. 2. 1899.

in oligoclase and the dark colored minerals, it is nevertheless thought to be a facies of the homogeneous syenite mass. The difference in mineralogical composition just noted might well be explained on the basis of differences in conditions of cooling and crystallization where the molten syenite was so thoroughly involved with the Grenville and its associated igneous rocks. Contact metamorphic effects must have been common and portions of the Grenville may at times have been absorbed by the molten syenite.

Another common type ranges from gray and dark gray to almost black, the color depending upon the biotite mica content, which is often very high. Other minerals which may be present are anorthoclase, oligoclase, quartz and smaller amounts of magnetite or hornblende. Rocks of this type usually appear as dark bands within the syenitic masses.

Other rocks ranging from light to dark color and containing garnets are thought to be Grenville, but they are so closely involved with other masses that they can not be mapped. Such a light colored feldspar rock with large garnets occurs along the railroad about 2 miles northeast of Anos Siding.

Another rock generally classed with the Grenville is rich in sillimanite and sometimes occurs in the complex as for instance at Forestport.

A rock type rich in hornblende and black in color occurs in distinct bands in the complex. A rock of this same character is found in the Grenville and was considered to be an old metamorphosed gabbro. Besides hornblende the rock contains feldspar ranging from oligoclase to labradorite and a little magnetite.

Another rock often present in very irregular masses and apparently cutting through all the others is a pegmatite. It is generally coarse grained and not in distinct veins.

All sorts of gradations occur between the types here described and these rocks in turn often grade into either the syenite or the Grenville masses proper.

Undetermined Precambric areas. Two areas have been indicated upon the geologic map as Precambric but of unknown character, because the rock masses are completely concealed from view by heavy glacial drift deposits. The area between Forestport and Enos is probably mostly made up of the Syenite-Grenville complex because those rocks bound the area both on the north and on the south. The area between West Canada creek and Little Black creek probably is syenite on the west and Syenite-Grenville on the east.

Paleozoic rocks

Potsdam sandstone and Beekmantown limestone. The Potsdam sandstone, which is the oldest of the Paleozoic formations bordering the Adirondacks, is certainly nowhere present at the surface within the map limits. There is evidence for believing that this sandstone is present along the southwestern border of the Adirondacks under cover of later formations. This question has been carefully discussed by Professor Cushing in his report on the Little Falls district.[1]

It is also true of the Beekmantown limestone that no exposures occur within the map limits. At Little Falls the Beekmantown (Little Falls dolomite) is something like 400 feet thick, but it shows a rapid thinning both northward and northwestward. In the vicinity of Cold Brook and Poland, and only a little over a mile from the southern boundary of the Remsen quadrangle, a considerable thickness of Beekmantown is shown. Thus, more than likely, it extends northward under the younger formations for a short distance at least on the Remsen quadrangle.

The Beekmantown comes close to where Black creek enters the map limits, but it seems to have disappeared before that point was reached. There is no evidence whatever to suggest the presence of Beekmantown in the northwestern part of the district.

Trenton formation. As here discussed the Trenton formation includes the Lowville limestone at the base, then possibly the Black River limestones and shales, with the Trenton limestone proper at the top.

The Lowville limestone shows in outcrop within the map limits only in the northwest along Black river. The outcrops are in the bed of the river and are well shown a short distance above the mouth of Crystal creek. The rocks are fine grained, compact, of a light bluish gray color and show many of the calcite filled tubes so characteristic of the formation. The layers are generally from 6 inches to a foot thick and constitute a very pure limestone. The exposed thickness of the Lowville here is about 10 or 12 feet and although neither the top nor the bottom is visible the maximum thickness can not be much over 30 feet. At the mouth of Crystal creek there is a Precambric outcrop only a few rods from the Lowville,[2] and a short distance west Trenton limestone is exposed.

[1] Geology of the Vicinity of Little Falls. N. Y. State Mus. Bul. 77. 1905.

[2] Along the western border of the Adirondacks the Lowville rests unconformably upon the Pamelia formation of Cushing. The Pamelia has been traced across the Port Leyden quadrangle by the writer and it is possible that just a trace of it may be present between the Precambric and the Lowville at Crystal creek.

Many outcrops of the Lowville may be seen extending along Black river from the locality here described to the type locality at Lowville. Just below the mouth of Crystal creek some of the limestone layers are clearly ripple marked. From trough to crest the ripples are usually less than an inch in hight, while from crest to crest the distance is only 1 or 2 inches.

The Lowville is nowhere exposed in the southern portion of the region, although a few miles off the map limits and between the villages of Newport and Poland, along West Canada creek, a thickness of over 20 feet may be seen.[1]

The Black River formation of the southwestern Adirondacks consists of a few feet of alternating limestones and shales lying between the Lowville and the Trenton, but not always present. Actual outcrops of the Black River are nowhere visible within the region here described, although the formation is probably present to a greater or less extent under cover of the Trenton proper. A few miles south of the map limits and along West Canada creek, between Newport and Poland, about 7 feet of Black River limestone and shale may be seen resting upon the Lowville. It also occurs at several localities within the Little Falls district.

Towards the northwest and a few miles off the map the Black River formation outcrops along Black river. Within the map limits, as above stated, the actual contact between the Lowville and Trenton opposite the mouth of Crystal creek can not be seen because of drift covering. Thus a thin layer of the Black River may possibly be present there.

The Trenton limestone proper occupies by far the largest territory or more than one third the area of the whole quadrangle. With the exception of the small Lowville area above described the Trenton rocks are thought to overlap everywhere upon the Precambric. In general this formation may be said to be made up of thin bedded, dark bluish gray, compact limestones separated by thin shaly layers, except the upper 25 to 35 feet which consists of thicker bedded, gray, coarse crystalline limestones with thin shaly partings. These rocks are everywhere highly fossiliferous, the limestone layers at times being made up almost entirely of shells.

The type locality for the Trenton limestone is along West Canada creek, at Trenton Falls, in the southern portion of the region under

[1] Prosser & Cumings. Sections and Thickness of the Lower Silurian Formations on West Canada Creek and in the Mohawk Valley. N. Y. State Geol., 15th An. Rep't. 1898. p. 628–29.

discussion. The most complete continuous section of the formation is here shown, which according to Prosser and Cumings has a measured thickness of 270 feet with neither top nor bottom exposed. The work of the writer to the west and northwest of Trenton Falls shows that the upper coarse crystalline beds are nowhere much over 35 feet thick and that the Utica shale rests directly upon these beds. Hence the uppermost beds of the Trenton Falls section must be within a few feet of the actual top of the Trenton.

The bottom of the Trenton is also not shown at Trenton Falls, although the dip of the strata and the presence of Beekmantown and Lowville limestone a few miles to the southeast make it appear very probable that the lowest beds at Trenton Falls must be close to the bottom. Allowing for the necessary addition to the top and the bottom, the thickness of the complete section at Trenton Falls is at least 280 feet and probably not more than 300 feet. In the section of the Globe Woolen Mills well at Utica the Trenton shows a thickness of 510 feet, while in the Rome well the thickness is given as 375 feet. Thus the Trenton shows a greater thickness both to the southward and the southwestward.

Because of the importance of the Trenton Falls section a somewhat detailed description is here given, although many more details may be found in the writings of Vanuxem,[1] Darton,[2] T. G. White,[3] Prosser and Cumings,[4] and Clarke.[5]

For $2\frac{1}{2}$ miles between the villages of Prospect and Trenton Falls, West Canada creek has cut a deep narrow gorge through the Trenton limestone. This gorge, with nearly vertical walls, varies in depth from 100 to about 200 feet and is commonly known as "Trenton chasm." In all there are six waterfalls varying in hight from a few feet to 128 feet. The principal falls are: Sherman fall, about 30 feet high and a short distance above the power house; High falls ($\frac{1}{4}$ mile south of the railroad bridge) consisting of an upper and a lower part with a total fall of 128 feet; the falls at the dam (just north of the railroad bridge) about 40 feet high; and Prospect falls (at the upper end of the gorge) 25 or 30 feet high. According to the topographic map the total drop of the stream within the $2\frac{1}{2}$ miles is about 360 feet. At the time of high water especially, the falls present magnificent sights. In spite of the steep slope of the

[1] Vanuxem, L. Geol. N. Y. 3d Dist. 1842. p. 45–56.
[2] Darton, N. H. N. Y. State Geol. 13th An. Rep't. 1894. 1:616–23.
[3] White, T. G. N. Y. Acad. Sci. Trans. 1895–96. 15:71–96.
[4] Prosser & Cumings. N. Y. State Geol. 15th An. Rep't. 1898. 1:615–27.
[5] Clarke, J. M. U. S. N. Y. Hdbk 15. 1899. p. 64–67.

View of the "Narrows," from lower end, with Sherman fall in the distance. The zone D^4, of White, well shown on the left bank. Lower Trenton limestone

Plate 2

N. H. Darton, photo.

Lower Trenton limestone, Sherman fall, Trenton Falls, Oneida co.

High fall, showing both the lower and upper parts. Middle Trenton limestone

stream bed the southward dip of the strata permits an exposure of only 270 feet of the rocks.

The lower Trenton limestones are dark bluish gray, thin bedded and fine grained with occasional coarser grained layers interstratified. Thin shale partings are nearly always present. On account of the dip the lowest beds are not found at the end of the gorge, but in the "Narrows" just above the power house. According to Prosser and Cumings[1] these rocks contain the following fossils:

1 Monticulipora (Prasopora) lycoperdon (*Say*)
2 Diplograptus amplexicaulis *Hall*
3 Trematis terminalis (*Emmons*) *Hall*
4 Rafinesquina alternata (*Con.*), *Hall & Clarke*
5 Strophomena *cf.* scofieldi *Winch. & Schuch.*
6 Orthis (Platystrophia) biforata (*Schl.*) *Bill.*
7 O. (Dalmanella) testudinaria *Dal.*
8 Plectambonites sericeus (*Sow.*) *H. & C.*
9 Zygospira recurvirostra *Hall*
10 Bellerophon bilobatus (*Sowerby*)
11 Asaphus platycephalus *Stokes*
12 Calymmene callicephala *Green* = C. senaria *Con.*
13 Ceraurus pleurexanthemus *Green* (?)
14 Crinoid segments

The middle Trenton limestones are mostly dark bluish gray, thin bedded, compact and with pronounced shale partings. According to Prosser and Cumings the middle Trenton fossils include:

1 Monticulipora (Prasopora) lycoperdon (*Say*)
2 Stictopora *sp.*
3 Rafinesquina deltoidea (*Con.*) *H. & C.*
4 Orthis (Platystrophia) biforata (*Schl.*) *Bill.*
5 O. (Dalmanella) testudinaria *Dal.*
6 Plectambonites sericeus (*Sow.*) *H. & C.*
7 Tellinomya dubia *Hall*
8 Endoceras proteiforme *Hall*
9 Cyrtoceras *sp.*
10 Asaphus platycephalus *Stokes*
11 Crinoid segments

The upper Trenton limestones are also dark bluish gray, thin bedded, and divided by shaly partings. The more compact strata are frequently interstratified with others which are somewhat crystalline. The upper 26 feet are light gray, coarse grained, crystalline limestones in thick beds which are separated by very thin shale partings. These coarse grained rocks are full of fossil fragments and are best exhibited in the quarries

[1] *Op. cit.* p. 622–23.

below Prospect. According to Prosser and Cumings the list of fossils includes:

1 Monticulipora (Prasopora) lycoperdon (*Say*)
2 Escharopora recta *Hall*
3 Trematis terminalis (*Emmons*) *Hall*
4 Rafinesquina alternata (*Con.*) *H. & C.*
5 R. alternata *var.* nasuta *Con.*
6 R. deltoidea (*Con.*) *H. & C.*
7 Strophomena *cf.* scofieldi *Winch. & Schuch.*
8 Orthis (Platystrophia) biforata (*Schl.*) *Bill.*
9 O. (Dalmanella) testudinaria *Dal.*
10 Plectambonites sericeus (*Sow.*) *H. & C.*
11 Zygospira recurvirostra *Hall*
12 Asaphus platycephalus *Stokes*
13 Calymmene callicephala *Green*
14 Ceraurus pleurexanthemus *Green*
15 Leperditia fabulites *Con.*
16 Endoceras proteiforme *Hall*
17 Orthoceras *sp.*
18 Bellerophon bilobatus (*Sowerby*)
19 Dendrocrinus gracilis (*Hall*)
20 Murchisonia gracilis (*Hall*)
21 Stictopora *cf.* acuta *Hall*
22 Crinoid segments

Highly contorted strata between undisturbed strata may be seen between the lower and upper portion of High fall, and also along the footpath especially opposite the crest of High falls. These phenomena will be discussed later under a separate heading.

Another Trenton section ranking next in importance to the one just described is that at Gravesville and extending from the village for more than a mile up Mill creek. A thickness of nearly 200 feet is here shown with neither top nor bottom exposed.

At Grant and extending for a half mile down Black creek a good section (20 to 30 feet) of lower to middle Trenton beds may be seen.

The upper Trenton limestones are well shown at Hinckley; between Trenton and Holland Patent; north and northeast of Steuben Valley; along Town Line (Cincinnati) creek from Prospect station (R. W. & O.) to Remsen; in the vicinity of Honnedaga and Bardwell Mill; and south of Alder Creek station. Besides these many smaller outcrops were found.

The upper, gray, coarse crystalline beds form the surface rock (largely covered by glacial drift) over most of the western portion of the Trenton limestone area. They are especially well shown near the Utica shale contact line.

Dolgeville (upper Trenton) shales. A series of alternating thin bedded limestones and shales, lying between the Trenton proper and the Utica shale, and found in the Little Falls district is called by Cushing the Trenton-Utica Passage Series.[1] Recently, however, Cushing has proposed the name Dolgeville (upper Trenton) shales

[1] *Op. cit.* p. 31–32.

Plate 4

N. H. Darton, photo.

Upper gorge, Trenton Falls, Oneida co. Upper Trenton limestone

Cliff on the east side of West Canada creek above the Adirondack Rail road bridge. The massive crystalline limestone is shown in the upper part of the cliff. Upper Trenton limestone

for these beds.[1] These rocks are absent from the Trenton Falls region except probably to a small extent in the extreme southeastern portion. They are mapped as occupying the extreme northwestern corner of the Little Falls quadrangle and hence would extend over, to a greater or less extent, upon the Remsen quadrangle. It is highly probable that these rocks are thus present although outcrops are nowhere shown because this region is so deeply covered by glacial drift as to completely conceal all underlying formations. The rocks of this series are transitional in character, the limestone layers being very similar to the Trenton while the shale layers are very similar to the Utica shale.

The Utica shale formation. The Utica shale, wherever present, rests directly upon the coarse crystalline beds of the upper Trenton. From the lithologic standpoint the formation is remarkably uniform and free from limestone or sandstone beds. The shale is black, thin bedded to even laminated, and because of its hardness and easy splitting is often popularly miscalled "slate." As seen upon the geologic map the shale is entirely confined to the western part of the quadrangle where it occupies most of the area west of the R. W. & O. Railroad.

The contact between the shales and the upper, coarse grained beds of the Trenton is a very sharp one although the lowermost beds of shale are more or less calcareous, thus showing that the change from limestone to shale is not so abrupt as the outward appearance of the rocks seems to indicate. The two formations may be seen in close proximity at several places along the stream beds to the north and northeast of Steuben Valley. Perhaps the best locality for observing the contact is along the railroad (R. W. & O.) about $\frac{3}{4}$ of a mile north of East Steuben station, where the shale and the coarse grained limestone are within 1 or 2 feet of each other. Beyond the map limits to the south, the sharp contact is well shown in the bed of Nine Mile creek, $1\frac{1}{2}$ miles southeast of Holland Patent. A low anticline here brings up the upper Trenton limestone with Utica shale resting on either limb.

The typical Utica shale beds extend well up on the sides of Starr hill where they reach an elevation of about 1560 feet. The lowest shale beds east of Starr hill lie at about 1250 feet. Hence the thickness of the Utica shale here must be something over 300 feet. A

[1] Since the appearance of the Little Falls report it has become evident that the formation therein mapped as " Trenton-Utica passage beds " is in reality a shaly eastern representative of the upper Trenton limestone of the type section, as I suggested at the time [N. Y. State Mus. Bul. 77, p. 63–64]. It seems also that this division is separable from the Trenton and Utica as a lithologic unit throughout the Mohawk valley. For this shaly phase of the upper Trenton I propose the name of Dolgeville shale, the full thickness with both contacts being exposed in the banks of East Canada creek just below Dolgeville. [*Signed*] H. P. CUSHING

thickness of approximately 600 feet in the southern part of the Little Falls district is given by Cushing. The record of the Campbell well near Utica shows 710 feet of the shale there. The deep well at Rome shows a thickness of only 300 feet of shale. Thus there seems to be a notable thinning of the Utica shale in passing northwestward.

Lorraine beds. The Lorraine beds of the Hudson River group appear at only one place within the map limits, namely at the top of Starr hill. The beds there show a thickness of about 200 feet with the top not reached. As is usually the case in central New York these lower beds appear to be destitute of fossils. Penn mountain and other high hills just west of the Remsen quadrangle are capped by the same formation.

There is no sharp line of demarcation between the Utica and the Lorraine and thus an exact boundry line can not be drawn. Passing upward the Utica black shales give way to generally lighter colored, rather more sandy shales containing frequent thin beds of gray sandstone. At times, however, the Lorraine shales closely resemble the Utica shales. Good exposures may be seen on the western side of Starr hill and also near the top of Penn mountain at about the 1700 foot level.

STRUCTURAL FEATURES

Folds

The Paleozoic formations show a very perceptible southwesterly dip but it is by no means uniform. For instance to the north of Remsen and in the vicinity of Honnedaga the limestone beds show very little departure from horizontality, while to the north of Steuben Valley they show a dip of approximately 100 feet per mile to the southwestward. Again in the bed of Mill creek, about a mile above Gravesville, the limestones show a very sharp dip of 15° to the southwest. In other cases the southwestward dip is just enough to be noticeable in the outcrops. Thus we see that strata which in a given locality lie almost horizontal may within a short distance show a comparatively steep dip giving rise to low folds whose axes extend northwest and southeast.

Another set of folds whose axes extend northeast and southwest are also more or less clearly distinguishable. Such are the folds accompanying the Trenton fault and fold (below described). A low anticlinal fold with similar strike has been observed to the northeast of Steuben Valley where along one stream the limestone

clearly dips to the west while along another stream a mile east the dip is southeastward. In the stream bed below Grant the limestone clearly dips northwestward thus suggesting the limb of a similar fold there. Off the map limits, about 2 miles southeast of Holland Patent and in the bed of Nine Mile creek, a very distinct anticline with northeast-southwest strike is exposed. The upper Trenton is here brought to view with shale dipping away on either side.

Aside from these larger folds numerous small ones occur, as for example in the bed of West Canada creek at Trenton Falls village.

Faults

Trenton fault and fold. A line of distinct faulting and folding passes from near Prospect village for 9 miles southwestward to

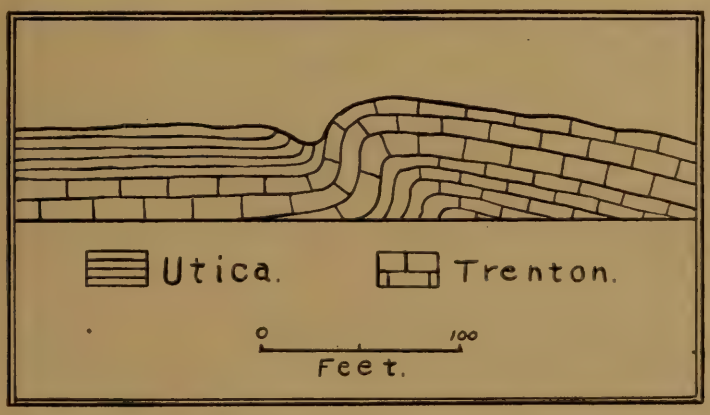

Fig. 1 Section across the line of sharp folding 2½ miles southwest of the village of Trenton. The minor faulting is not shown in the drawing.

Stittville beyond the map limits. The line of disturbance is almost straight and beginning east of Prospect, it passes near Prospect station (R. W. & O. R. R.), just west of Trenton, thence off the map through Holland Patent and to Stittville. That portion of the line between Trenton and Holland Patent has been very briefly described by Darton,[1] but the more important part lying between Trenton and Prospect is here described for the first time. The writer has called the whole line of disturbance the Trenton fault because it passes through the town of Trenton. The Trenton fault is of interest for several reasons: because it is the most westerly of all the series of Mohawk valley faults yet described; because it is the only one of the series which shows thrust faulting; and because it is one of a very few which have the downthrow side on the west. Two other faults of the series having downthrow on the west are the Dolgeville fault and the branch of the Little Falls fault.

[1] N. Y. State Geol. 14th An. Rep't. 1895. p. 52–53.

Between Trenton and Holland Patent the disturbance has manifested itself chiefly as a sharp anticlinal fold with a steep western front accompanied by comparatively slight faulting. The above figure shows the condition of things here according to the writer's conception.

According to Darton[1] normal faulting has been the principal cause of the displacement and as a result of slipping, the Utica shales, on the downthrow side, have been bent upward while the limestone beds on the upthrow side have been bent downward. According to him the upper Trenton has been sharply faulted against the Utica, the amount of displacement being possibly as much as 60 feet. A careful study of the limestone-shale contact has failed to reveal any such sharp or extensive faulting as suggested by Darton. According to the writer the steep dips of the limestone and shale are due entirely to the development of an anticline whose western limb is very steep and sometimes nearly vertical so that it approaches the overturned type. As a result of the folding and later removal of shale by erosion the limestone beds do appear displaced or raised above the level of the shale The difference in level is often 40 to 60 feet as Darton suggests but it is not due chiefly to faulting.

If the lateral pressure which formed the anticline had continued, a typical overturned fold and finally a thrust fault would have developed. As it is, the only evidence of faulting is within the body of the limestone itself, near the shale contact, where small thrust faulting may occasionally be seen. All along the line between Holland Patent and Trenton the harder, more resistant limestone beds stand out as a low sharp ridge while the softer shales on the west have been worn down.

In the vicinity of Prospect station 1½ miles southwest of Prospect there is also abundant evidence of disturbance. Here, however, upper Trenton limestones only are present. Along the small streams just north of the station they are seen to be strongly folded, in one case the limestone beds standing in vertical position. Also to the west of the station in the bed of Cincinnati (Town Line) creek the limestone beds are much disturbed by folding. In this vicinity some minor faulting has been noted although for most part the disturbance shows itself in the folding.

Between Prospect station and Prospect village the country is deeply drift-covered, while at Prospect occurs the principal disturbance visible along the line. A thrust fault of considerable

[1] *Op. cit.* p. 52–53.

Plate 6

W. J. Miller, photo.

Looking westward and parallel to the strike of the fault at Prospect. On the right are thick beds of the upper Trenton; on the left are highly inclined, thin bedded middle Trenton strata; while between are broken and crushed middle Trenton rocks. The water's edge on the right lies along the fault plane.

throw is clearly exhibited in the creek bottom between Prospect falls and the highway bridge. The topographic map is here not accurate in detail and the following sketch map will give a better idea regarding the location of the fault.

Before reaching the falls the stream flows due west and at the falls makes a sharp turn to flow about 200 yards east-southeast till the fault line is struck. At the latter point another sharp turn is

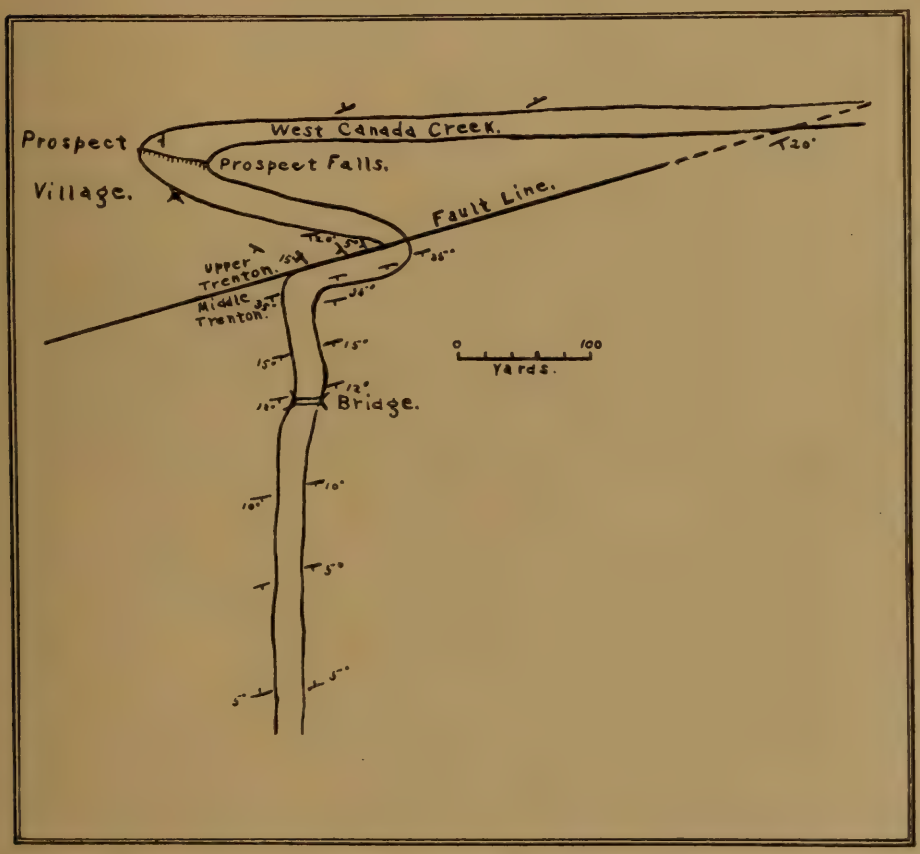

Fig. 2 Sketch map showing the course of West Canada creek and the position of the fault near the village of Prospect

made so that the stream flows west-southwest for 50 or 60 yards, and parallel to the fault line. Then the course of the stream is due south to the highway bridge. Where the creek flows parallel to the fault line the fault plane is clearly exposed and in reality forms the north bank of the creek [*see* pl. 6 and 7]. The strike of the fault is n. 70° e. and the dip of the fault plane is 55° to the south. It is a thrust fault with the downthrow side on the north [*see* fig. 3]. The rocks on the downthrow side are the thick bedded, coarse crystalline limestones belonging at the summit of the Trenton formation. These rocks form a bold rocky point extending

eastward to the creek and they show variable dips of from 5° to 15° a little to the south of west. The rocks in the creek bed on the upthrow side of the fault are middle Trenton limestones. A short distance away from the fault plane these rocks are highly inclined showing a uniform maximum dip of 35° a little to the east of south. Continuing southward to the bridge higher and higher Trenton strata are seen and the dip gradually diminishes to 12°. Below the bridge the dip continues to decrease until finally at about 150 yards the strata lie in a horizontal position and the coarse limestone of the uppermost Trenton is visible at the top of the gorge. Still farther southward the rocks dip northward at a low angle.

In the immediate vicinity of the fault and on the upthrow side the rocks are highly crushed and folded. This crushed zone is

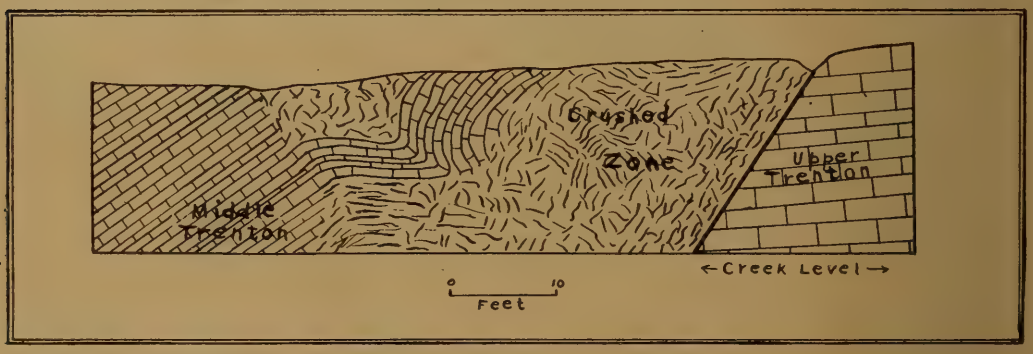

Fig. 3 Section showing the condition of things at the fault near Prospect. Looking southwest and parallel to the fault plane

about 40 feet wide [*see* fig. 3]. The rocks on the downthrow side are not crushed and the fault plane is shown as a smooth clean break [*see* pl. 7]. Along the fault plane slickensides are common and also fault breccia made up of limestone fragments which have often been recemented by white coarse crystalline calcite. On both sides of the main fault plane there are a number of fault slips of very small throw which represent minor fracturing in the immediate vicinity of the main fault. Except for a slight southwestward dip the strata at Prospect falls show no sign of disturbance.

Because of the existence of the wide crushed zone on the upthrow side the character of the folding in that zone can not be determined. Hence the exact throw of the fault can not be given although it can be fairly well approximated. As a result of the faulting the beds of the middle Trenton have been brought up to the level of the coarse crystalline beds of the upper Trenton and hence the fault must be of the thrust or reversed type. A measurement by the

Plate 7

W. J. Miller, photo.

Looking north upon the fault plane at Prospect. Except at the extreme left, the whole rock surface shown is that of the fault plane itself. The dark streak near the left margin and nearly under the small dead tree represents the contact between the crushed middle Trenton and the heavy bedded upper Trenton.

writer of the thickness of the upturned strata from the base of the coarse crystalline beds to the crushed zone at the creek level near the fault plane gave 140 feet. This result corresponds to within a few feet of the thickness obtained by Prosser and Cumings for the same set of strata farther down the gorge. According to those authors the conspicuously contorted stratum opposite the top of the lower fall of High fall occurs just above their zone A^5 or 144 feet below the top of the Trenton. This same contorted stratum has been traced by the writer to near the fault and between it and the fault there intervenes a thickness of 25 or 30 feet of still lower strata. It is evident therefore that the beds as low at least as the upper part of Prosser and Cumings zone A^5 are thrown by faulting against the gray crystalline upper Trenton beds. Thus the stratigraphic throw of the fault (disregarding the crushed zone) is something like 140 feet. The throw or vertical displacement is probably from 30 to 50 feet greater than the stratigraphic throw. Because of the high angle of dip of the fault plane the heave (horizontal displacement) must be considerably less than the throw.

Upturned strata are often present among the shales on the downthrow sides of the Mohawk valley faults. They are due to an updragging effect produced by normal faulting. At the Trenton fault, however, the strata are upturned on the upthrow side and were bent upward by the lateral pressure which first probably developed a fold and later a fracture so that the middle Trenton rocks were pushed upon the upper Trenton.

Where the fault line would be expected to cross the creek about $\frac{1}{4}$ of a mile eastward the only sign of disturbance is a small but very distinct fold in the limestone beds. Thus the fault above described dies out so rapidly that within the $\frac{1}{4}$ mile it is entirely gone and passes into a small fold. Beyond this the line of disturbance can not be traced because of heavy drift deposits.

Minor faults. A number of small faults have been noted along the gorge between High fall and Prospect but the throw is always slight. The Trenton rocks have been considerably disturbed by folding and faulting on Mill creek and one of its tributaries about a mile above Gravesville. Sharp folding is well shown where the line crosses Mill creek (at the mill), while folding accompanied by faulting of unknown though small extent is exhibited where the line crosses the tributary (the second one above Gravesville) a quarter of a mile above its mouth. This line of disturbance strikes n. 70° w. and it can not be traced across country.

Dip of the Paleozoic formations

As the Paleozoic rocks were originally laid down nearly horizontally movements since their deposition have caused them to have a general southwestward dip. The amount of the dip is usually small and may be clearly demonstrated by comparing the altitude of given horizons within the Trenton at different places.

At Trenton Falls the top of the Trenton limestone is 1100 feet above sea level, while the same horizon was struck at 142 feet below sea level in the Globe Woolen Mill well at Utica. Thus the difference in elevation of the same horizon between these points 14 miles apart is 1242 feet, showing a southward dip of 90 feet per mile.

Again, the top of the Trenton 1 mile south of Alder Creek station is at 1280 feet, while the same horizon in the Rome well is 205 feet below sea level. The difference in elevation is 1485 feet and the distance is 18 miles, which shows a dip of 82 feet per mile for the limestone.

At Grant, lower Trenton is exposed at 1200 feet, while at Gravesville 5 miles to the southwest the same beds lie at 900 feet, thus giving a dip of 60 feet per mile.

The difference in elevation between the top of the Trenton at Bardwell Mill and Remsen, which places are $4\frac{1}{2}$ miles apart is approximately 40 feet, thus giving a dip of 9 feet per mile.

Over the western part of the town of Remsen the strata must lie almost horizontal as shown by the outcrop of the upper Trenton over such an area at practically the same elevation.

Uppermost Trenton beds are shown at Remsen and also at a point $1\frac{1}{4}$ miles northeast of Steuben valley. The distance between these points is $2\frac{1}{2}$ miles and the difference in elevation is about 250 feet, so that here the southwestward dip is about 100 feet per mile.

Certain marked variations from this general southwestward dip due to the development of the Trenton fault and fold have already been described.

Joints

The Precambric rocks are everywhere highly jointed and the joint planes are always vertical or at high angles. After many observations the writer has not been able to make out any well defined system. Even over short distances the directions are very variable. Locally, however, two well developed joints may generally be seen crossing each other at rather high angles. Besides these other minor and irregular joints are present.

The Paleozoic rocks, too, are thoroughly jointed and, as in the case of the Precambric rocks, these joints are mostly nearly verti-

cal. Although these joints show great variation in direction and degree of development, nevertheless over most of the Paleozoic area two sets running approximately east-west and north-south appear to predominate. These are particularly well seen in the vicinity of Trenton Falls and Remsen. The vertical walls of the gorge at Trenton Falls are principally due to the breaking away of large limestone masses along the north-south joint planes. The east-west joints may here be seen extending across the stream at many places, but especially at the falls themselves. The falls are all due to the existence of the joints since when a large mass of limestone is removed a vertical wall is left over which the water falls. Thus the falls retreat and reform by the removal of joint blocks as, for example, in the case of Sherman fall. Here at high water the water falls over one joint plane on the eastern side and over another a number of feet back on the west side. When the water is low it all passes over the rear joint on the west [*see* pl. 2]. It is very evident that, in the course of time, the whole block of limestone left between the two joints will be removed.

In the bed of Cincinnati (Town Line) creek, from 1 to 1½ miles below Remsen an interesting drainage feature is due to the joint planes in the coarse crystalline (upper Trenton) limestones. Several hundred yards above the bridge, at time of low water, the stream disappears entirely through the joints and after a subterranean course, mostly along the joints, it reappears near the bridge.

Foliated structure

A foliated or gneissic structure is highly characteristic of all the Precambric rocks. It is exhibited best of all in the ancient Grenville sediments, next best in the rocks of the Syenite-Grenville complex, and least in the pure syenite. The excessive foliation of the Grenville is accentuated by the alternating light and dark bands above described. The foliation of the syenite though distinct is brought out only by the dark, narrow, irregular, wavy streaks passing through the otherwise homogeneous rock mass.

As a result of many readings it may be stated that the Precambric foliation planes all show a strike varying between n. 60° e. and n. 80° e. This result agrees closely with that obtained by Cushing for the Little Falls quadrangle and for the Long Lake quadrangle of the mid-Adirondacks. The dip of the foliation planes is sometimes north and sometimes south but nearly always at very high angles. Often the Grenville and the Syenite-Grenville complex rocks are locally highly plicated or crumpled

It is interesting to note that the strike of the Trenton fault and fold, as well as the strike of a number of low folds within the region corresponds closely to the strike of the Precambric foliation planes. This shows that the pressures so different in intensity and which produced both sets of phenomena so widely separated in time, acted in the same direction.

Contorted strata within the Trenton [1]

Excellent examples of highly folded or contorted strata between nonfolded strata may be seen along the sides of the gorge at Trenton Falls. Dr J. M. Clarke has called the writer's attention to a similar case of interbedded contorted limestones described by Sir

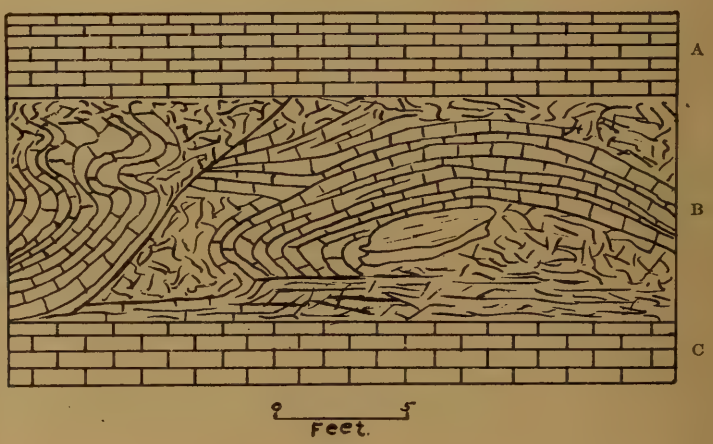

Fig. 4 Highly folded and broken strata between nonfolded strata as seen along the footpath opposite the crest of High falls. Drawn from nature

William Logan[2] and occurring on the Forillon peninsula of Gaspé, along the Gulf of St Lawrence. According to Clarke[3] these contortions lie in the Cape Bon Ami beds of the lower Devonic.

At Trenton Falls the folded beds lie at two distinct horizons within the Trenton limestone. According to Prosser and Cumings[4] who have made careful measurements of the thickness of the limestone at this locality, the base of the lower contorted zone lies 144 feet below the top of the Trenton. This zone is from 4 to 6 feet thick and is visible only at the crest of the lower part of High fall and in the upper end of the gorge near Prospect where the strata are highly inclined [*see* pl. 8]. Using the measurements of Prosser and Cumings the base of upper folded zone lies about 65 or 70 feet

[1] *See* paper by the writer in Jour. Geol. 1908. 16:428–33.
[2] Geol. Can. 1863. p. 391–92.
[3] N. Y. Mus. Mem. 9.
[4] N. Y. State Geol. 15th An. Rep't, p. 615–27.

Plate 8

T. G. White, photo.

The lower contorted and broken zone as seen near the crest of the lower part of High fall (From N. Y. Acad. Sci. Trans. v. 15, pl. III, fig. A)

below the top of the Trenton. This zone varies from about 8 to 15 feet in thickness and is well shown along the path opposite High fall. From this point it may be traced along the sides of the gorge for nearly 2 miles to Prospect village.

The impure limestone layers of both the folded and the non-folded portions average only a few inches in thickness and are separated by thin shale bands. Within the folded zones the layers are, in rare instances, scarcely folded or broken; sometimes they are gently folded; most commonly they are highly folded or contorted; while occasionally some of the layers are broken and pushed or faulted over others.

Numerous observations show the strike of the folds to be from n. 50° e. to n. 65° e. or practically parallel to the strike of the Trenton fault and also parallel to the very low folds of the Trenton limestone in this region.

It should be noted that these contorted strata occur only in a very local district. As far as can be ascertained they are visible only in the Trenton Falls gorge and in the bed of Cincinnati creek, 1½ miles southwest of Prospect. Along Mill creek, above Gravesville, the contorted strata do not show in the excellent Trenton section there exposed.

Cause of the folding. Vanuxem[1] states that the folded layers are more thoroughly crystalline than the layers above and below and that as the material of the disturbed layers was being crystallized it caused an expansion which manifested itself laterally by throwing the layers into folds. However a careful study has failed to show any real difference in degree of crystallization and even if such difference could be found it is difficult to see how simple crystallization could bring about such a considerable expansion.

T. G. White[2] cites Prof. W. O. Crosby as suggesting that the folds may have been caused by the great weight of overlying strata. But this does not explain the sharp and even overturned folds and minor thrust faults which imply a distinct shortening of the layers within the folded zones.

In some places the structure greatly simulates cross-bedding. White[3] gives photographs showing supposed overlap structure and channel filling. Since these structures are associated in the same zone, with truly folded and broken strata some other explanation must be sought.

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[1] Geol. N. Y. 3d Dist. 1842, p. 90.
[2] N. Y. Acad. Sci. Trans. 15:89-90.
[3] *Op. cit.* pl. 3, fig. B and pl. 4, fig. B.

It has occurred to the writer that the cause may have been a lateral compression which caused most of the limestone beds to become denser without being folded, while certain other layers yielded by folding. This would seem to imply a greater rigidity for the folded zones, but if anything the evidence points to less rigidity.

Regarding the Canadian occurrence above referred to Logan says: "It would appear as if the layers after their deposit had been contorted by lateral pressure, the underlying stratum remaining undisturbed, and had then been worn smooth before the deposition of the next bed. Where the inverted arches of the flexures occur some of the lower layers are occasionally wanting, as if the corrugated bed had been worn on the under as well as the upper side." But it is difficult to see how such a lateral pressure could cause certain layers to become highly folded and broken while the layers immediately below them are undisturbed. Also the apparently worn character of the upper and lower sides, mentioned by Logan and which is likewise true of the Trenton Falls occurrence, is left without explanation.

It is thought that the folded structure at Trenton Falls was, in reality, caused by a differential movement within the mass of the Trenton limestone. That the whole body of the limestone has been moved is clearly demonstrated by the existence of the thrust fault at Prospect. It is easy to see how when the force of compression was brought to bear in the region there would be a tendency for the upper Trenton beds on the upthrow side to move more easily and consequently faster than the lower Trenton beds. For instance the portion A in figure 4 being separated from C by an intermediate mass B of slightly less rigidity, would slide over C and cause the portion B to become ruffled or folded. Occasionally parts of B would become fractured or faulted. A similar explanation would also apply to the lower folded zone. The folded zones thus merely indicate horizons of weakness along which the differential movement has taken place.

As thus explained it is evident why the strike of the minor folds, the strike of the fault, and the strike of the large low folds of the region should all be parallel and why the contorted strata should be so local in occurrence, because all these phenomena were produced by the same local pressure. The differential movement would also readily account for the rubbed or worn character of the upper and lower sides of the contorted zone.

It is interesting to note that similar phenomena of contorted between nonfolded strata have been observed in clay banks of

Pleistocene age along Black river to the north of Trenton Falls and also along the Canal feeder west of Forestport. The latter occurrence has been described and figured by Vanuxem.[1] Regarding this phenomenon Vanuxem says: "No cause can reasonably be assigned but different degrees of lateral pressure." The folding is often so great, however, that the required differences in degree of lateral pressure are altogether too great. The writer believes that, in principle, the explanation given for the contorted limestones may apply here also, except in the case of the clay beds the movement of upper over lower masses may have been caused by ice action or by having been pulled down the hillside by gravity. Or as Salisbury and Atwood[2] have suggested for such a phenomenon in Pleistocene clay, that the cause may have been lake ice or "the grounding of an iceberg on the surface before the overlying layers were deposited." In any case the cause of the movement in these superficial clays is very different from that of the ancient Trenton limestones. Such interbedded contortions are very common in the Pleistocene clays of New York, especially along the Hudson river valley.

THE PALEOZOIC OVERLAP

As already stated the Paleozoic rocks overlap upon the Precambric. This was caused by a gradual sinking of the Adirondack region while Paleozoic deposition was going on, so that the younger formations encroached farther and farther upon the sinking land mass.

Since the Potsdam sandstone nowhere outcrops along the southwestern border of the Adirondacks, any evidence for its presence as the lowermost of these overlapping formations must be sought for in deep well sections. This question has been clearly discussed by Professor Cushing who uses data furnished by both Prosser and Orton.[3] The writer here merely wishes to state the general conclusion that in the Ilion, Utica and Rome wells the presence of Potsdam sandstone has not been definitely proved because of the difficulty in distinguishing Beekmantown and Potsdam on the one hand and Potsdam and Precambric on the other. Farther northward in certain Oswego county wells the presence of the Potsdam has been demonstrated. Since the Potsdam does not outcrop along the Precambric boundary line east of these wells it is evident that younger formations overlap it upon the Precambric.

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[1] *Op. cit.* p. 214–15.
[2] Jour. Geol. 1897. 5:143.
[3] Geology of the Vicinity of Little Falls. N. Y. State Mus. Bul. 77. 1905. p. 51–56.

Although the Beekmantown is not exposed within the map limits there is no question regarding its presence as an overlapping formation. In the northwest corner of the quadrangle, along Black river, the Lowville and Precambric are so close together as to preclude the presence of Beekmantown. Near the south boundary at Cold brook, the Beekmantown is exposed and doubtless extends northward under the Trenton. In the wells to the south and southwest at and near Utica and at Rome, the Beekmantown is present showing a thickness which is not accurately known, but which is quite certainly at least several hundred feet. Passing northwestward from these wells to the Precambric boundary the Beekmantown shows a diminution in thickness from several hundred feet to nothing, which is just what would be expected in the case of overlap.

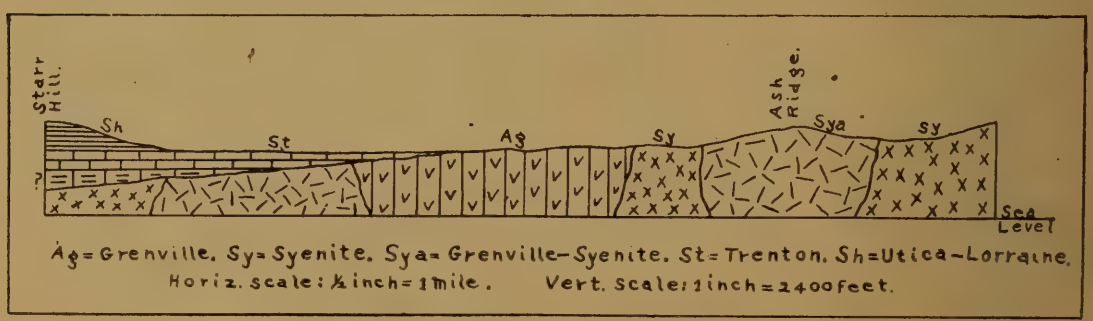

Fig. 5 Structural section across the region passing from Starr hill east-northeast and through Ash ridge

Within the map limits the Trenton formation, so far as can be determined, everywhere rests upon the Precambric, along the Precambric boundary. Along Black river, in the northwestern part of the quadrangle, the Lowville may be seen practically in contact with the Precambric. Thus the facts clearly show that the Trenton overlaps the Beekmantown upon the Precambric.

The Trenton shows a thickness of 510 feet in the Globe Woolen Mill well at Utica, 575 feet in the Chittenango well, and 435 feet (including the Lowville) in the Rome well. Within the Remsen quadrangle the maximum thickness of the Trenton including the Lowville is about 300 feet. Along the Precambric boundary there is strong evidence to show that the thickness of the Trenton is much less. Such evidence may be found along the line between Bardwell Mill, where upper Trenton is shown, and the mouth of Little Black creek where Precambric outcrops. When the difference in elevation and the greatest possible slope of the Precambric surface between these points are considered, it is evident that no

such thickness as 300 feet of limestone can here be present. In other words a well starting at the top of the Trenton at Bardwell Mill would strike the Precambric much short of 300 feet. The thickness of the Trenton here is probably not much over 150 feet. This thickness compared with the greater thickness at Trenton Falls and in the wells farther south and southwest is what would be expected in the case of an overlap.

THE PRECAMBRIC SURFACE

Smoothness of the floor upon which the Paleozoics were deposited

There is considerable evidence to show that the Precambric floor which received the Paleozoic sediments was a comparatively smooth one (peneplain). Although the exact boundary line between the Paleozoic and Precambric rocks can not be drawn because of the heavy drift covering, nevertheless there are sufficient exposures on either side to indicate that the line is at least a fairly regular one as shown upon the map. Such a boundary line would be caused by deposition of sediment upon a smooth surface and by later elevation when the sediments would tend to wear off rather regularly.

Or again the smoothness of the Precambric floor is suggested by the absence of isolated Paleozoic areas within the general Precambric district and also by the absence of isolated Precambric areas within the general Paleozoic district. If the Precambric floor had been a rough surface, isolated areas (outliers and inliers) would be expected, near the boundary line at least, where on the one hand sediments had been filled into deep Precambric depressions or on the other hand where Precambric knobs or hills would protrude upward into the sediment and by later erosion become exposed to view. Such outliers or inliers have nowhere been found.

If the depressions occupied by the present streams of the Precambric area were completely filled the resulting surface would be a comparatively smooth one sloping southwestward. This strongly suggests that the old floor was fairly smooth and that the rather rugged topography now existing has been produced almost entirely by stream erosion since the stripping off of the sediments.

There is reason to believe that the surface was not entirely free from small hills or knobs which rose above the general level. In the adjoining Little Falls district Professor Cushing has described a very clear-cut example of such a knob at Diamond hill[1]. Myers

[1] N. Y. State Mus. Bul. 77. p. 57–58.

hill in the north central part of the Remsen quadrangle may possibly represent such an ancient hillock. This hill rises abruptly almost 200 feet above the surrounding country and is separated from a still higher hill to the northeast by a narrow depression. This depression is difficult of explanation on the basis of the existing drainage, but it may be readily accounted for by the action of a Precambric stream.

Slope of the surface upon which the Trenton was being deposited

Not far beyond the map limits to the southeast the Trenton shows an increase in thickness, towards the southwest, of about 100 feet in 5 miles. This indicates that the slope of the surface on which the Trenton was being deposited was about 20 feet per mile southwestward.

The thickness of the Trenton formation (including the Lowville) at Trenton Falls is probably not far from 300 feet. In the Globe Woolen Mills well at Utica it is 510 feet, which is an increase of 210 feet in the distance of 14 miles. Hence the slope of the floor here upon which the limestone was laid down was about 15 feet per mile southward.

In the Rome well the Trenton is 375 feet thick and 20 miles to the northeast it is from 200 to 250 feet or an increased thickness northwestward of from 125 to 175 feet. This indicates that the surface receiving limestone deposition sloped 6 or 8 feet per mile southwestward.

Thus the general facts seem to be that the floor upon which the Trenton was being laid down sloped 6 or 8 feet to 20 feet per mile southwestward and that the slope was less in the northwestern part of the region.

Present Precambric slope beneath the Paleozoics

At Northwood the Precambric lies at an elevation of 1220 feet, while in the Campbell well near Utica it was struck at 1500 feet below sea level. The distance between the points is 21 miles and the difference in Precambric elevation is 2720 feet which shows a present Precambric slope of 130 feet per mile southward.

The Precambric at Forestport lies at 1140 feet and in the Rome well at 1105 feet below sea level, thus showing a difference in elevation of 2245 feet in a distance of 20 miles or a slope southwestward of about 110 feet per mile.

In the same way the difference in elevation between the Precambric at Forestport and at Vernon is found to be 2965 feet.

The distance between the places is 30 miles and hence the slope southwestward is about 100 feet per mile.

Slope of the surface where no Paleozoics now cover

At Forestport the Precambric outcrops at 1140 feet and 6 miles northeastward at 1500 feet. The difference in elevation is 360 feet or the southwestward slope is 60 feet per mile.

At the mouth of Little Black creek the Precambric lies at 1180 feet and 1½ miles north of Reeds Mill it lies at 1900 feet. The distance is 10 miles and the difference in elevation is 720 feet. Hence the Precambric slope is here 72 feet per mile southwestward.

At Northwood the Precambric is exposed at 1220 feet and 10 miles northeastward at 2210 feet, showing a difference in elevation of 990 feet. The slope southwestward is thus nearly 100 feet per mile.

From these considerations it is evident that the general Precambric slope where not now covered by the Paleozoics is much less steep than where covered. This marked difference is readily accounted for by erosion and gives us some idea of the amount of erosion in the Precambric surface since the Paleozoics were removed. The original dip of the Paleozoics was found to be 50 to 100 feet per mile which is considerably less then the slope of the Precambric beneath them. Also the dip of the Paleozoics is very nearly the same as the present slope of the Precambric where no Paleozoics cover.

ABSENCE OF THE DOLGEVILLE (UPPER TRENTON) SHALES

The Dolgeville shales, formerly called the Trenton-Utica passage series, and described by Cushing are always present between the Trenton proper and the Utica shale in the Little Falls district.[1] The rocks of the series are rather thin bedded, alternating limestones and shales and are distinctly transitional in character. A maximum thickness of about 100 feet is shown in the Little Falls district. Over the entire Remsen quadrangle such transitional beds are nowhere exposed, although the Trenton limestone covers a wide area and in a number of places the Utica and Trenton may be seen in close proximity if not in actual contact. A small area in the southeast corner of the quadrangle especially that portion known as Sand hill, is probably occupied by the Dolgeville shales which here represent the northwestward extension of the same

[1] *Op. cit.* p. 31–32. *See also* p. 20 of this report.

formation as mapped upon the Little Falls quadrangle. Sand hill and vicinity are covered by very deep glacial drift so that no rock exposures whatever may be seen to make the mapping certain.

The characteristic absence of the Dolgeville shales over the Remsen district as opposed to their presence over the Little Falls district calls for an explanation. A careful comparison of the sections in the two regions shows that the difference is probably not as great as at first sight appears. The sections are here given for comparison.

Type section in the Trenton Falls district

3	Utica shale 300+ft	Thin bedded black shales somewhat calcareous at base. (Sharp contact)
2	Upper Trenton limestone 140+ft	*b* Thick bedded, coarse grained, gray crystalline beds, 30 ft. (Fairly sharp contact)
		a Thin bedded, impure beds with pronounced shale partings. 110+ft. (No sharp contact)
1	Lower Trenton limestone 140+ft	Thin bedded, impure limestones with thin shale partings

Type section in the Little Falls district

3	Utica shale (as above) 600+ft	(No sharp contact)
2	Dolgeville shales 100 ft	Thin bedded, alternating limestone and shale layers of about equal thickness. (No sharp contact)
1	Trenton limestone 100 ft	Thin bedded impure limestones with thin shale partings

These sections show a rapid thinning of the Trenton southwestward. Even when the Lowville and Dolgeville shales are included with the Trenton proper in the Little Falls district, the thickness is only 200 feet as opposed to nearly 300 feet for the Trenton formation at Trenton Falls. This thinning continues southeastwardly to Canajoharie. Thus a slower rate of subsidence eastward while the limestones were forming was doubtless an important factor in causing the thinning in that direction. But as Cushing has suggested, a change in lithologic character of the

formation across country might well be considered. From the lithologic standpoint the most striking difference comes from a comparison of the upper Trenton on the one hand with the Dolgeville on the other. The removal of the thin mass of coarse crystalline limestone from the Trenton Falls section and an increase in thickness of the shale partings in the rest of the upper Trenton there would result in a formation like that of the Dolgeville shales. Such a change could have been effected by comparatively small differences in conditions of deposition. This argument comes to one with special force while looking at the thick mass of thin bedded limestones with pronounced shale partings just beneath the coarse crystalline limestone at Trenton Falls. The presence of the pure coarse crystalline limestones around Trenton Falls signifies clearer water conditions and the sharp contact with the Utica shales signifies the sudden advent of muddy water, although the sharpness of the contact is somewhat modified by the calcareous character of the lower shale beds. In the vicinity of Little Falls the transition from limestone to shale was more gradual. Thus we see that the upper Trenton of Trenton Falls is in all likelihood to be correlated with the Dolgeville of the Little Falls section; that these correlated portions are lithologically not greatly different; and that comparatively slight changes in the conditions of deposition readily account for the absence of the Dolgeville shales in the Trenton Falls district.

Minor evidences to show local changes in sedimentation in the lower part of the Trenton formation near Little Falls are to be found in the only occasional presence of the Black River beds and the great variations in thickness of the Lowville.

GLACIAL GEOLOGY

In the Trenton Falls district there is abundant evidence to prove the former presence of the Post-tertiary ice sheet. The evidence consists chiefly in the glacial drift such as the till, morainic deposits, and the general sand and gravel deposits which are so widely scattered over the Remsen quadrangle. Sometimes large areas are so thoroughly drift covered that the underlying formations are completely concealed from view. The heaviest accumulation of drift appears to be over a broad area extending from southeast to northwest across the map. In this area scarcely an exposure can be found except here and there along the stream courses where the drift has been worn through.

The full significance of the glacial deposits of the Remsen quadrangle will not be known until careful work has been done in the contiguous areas and in fact along the whole Mohawk valley. The writings of Chamberlin,[1] Brigham[2] and Cushing[3] are here referred to as bearing directly upon the subject. Brigham, whose work is particularly noteworthy, is now engaged in further study of this problem. The discussion here presented is decidedly local in its character, the purpose being merely to record certain observations and to offer some suggestions which bear upon the broader problem.

Ice erosion

As the ice slowly moved across the country the preglacial rock surface was more or less scratched and eroded, but there is no good reason for thinking that the old rock surface was profoundly affected in this way. In the western part of the district, and extending out for a considerable distance from the shale area the heavy crystalline beds of the upper Trenton nearly always make up the surface rock formation and no isolated shale masses can be found. The shale rises rather abruptly above the limestone area culminating in the high land around Starr hill. The writer inclines to the belief that immediately before the advent of the ice, thin shale masses extended farther eastward over the limestone. Certain it is that at one time the shale did thus extend out and that it has been removed either by water erosion or by ice erosion. As the ice moved across the country the tendency would be for the softer shales to be more easily removed than the more resistant heavy beds of limestone. Both types of erosion should be considered and no doubt the stripping off action of the ice was important. Among the evidences favoring this view are: the presence of the thin mass of coarse crystalline limestone over such a wide area; the greater resistance to erosion of the limestone; the prevalence of glacial till full of shale fragments and directly overlying the limestone.

Direction of ice movement

Chamberlin, in the report above referred to, makes the tentative statement " that strong ice currents swept around the Adirondacks and entered the Mohawk valley at either extremity, while a feebler current, at the hight of glaciation probably passed over the Adirondacks and gave to the whole a southerly trend." Observations by later investigators have tended to bear out this view. This con-

[1] U. S. Geol. Sur. 3d An. Rep't., p. 361–65.
[2] Geol. Soc. Am. Bul. 9, p. 183–210.
[3] N. Y. State Mus. Bul. 77, p. 73–81.

clusion is based upon the direction of glacial striations and upon the distribution of glacial deposits and topographic forms.

As regards rock striations the writer has but a single observation to record and that is an unsatisfactory one. The striations occur upon the syenite along Big Woodhull creek, 2 miles northeast of Forestport. They bear approximately s. 30° e.[1] The general northwest-southeast distribution of the moraine deposits [*see* below] agree closely with the reading above given. Also the abundant shale fragments in the till to the north and east of Remsen and Prospect were very largely derived from the shale around Starr hill and this implies a general southeastward movement of the ice. Down the Mohawk valley the striations and topographic forms show an east and west arrangement. Along the northwest border of the Adirondacks, as near Clayton, the writer has seen many striations pointing southwestward. All these facts are clearly in harmony with the idea of Chamberlin above quoted. Since the Trenton Falls district is situated along the southwestern side of the Adirondacks a southeastward movement would be expected such as the records suggest. At the hight of glaciation however this ice current must have given way largely to the more general southward current across the Adirondacks. The distribution of erratics [*see* below] over the Remsen quadrangle as well as for many miles southward confirms this belief.

Glacial till

Glacial till or ground moraine material is exposed at many places throughout the district. Over the Precambric area the exposures are not so common and the material is characteristically light colored, very sandy and full of coarse gravel as may well be seen along the State road west of Reeds Mill. The rock fragments in this till represent various Adirondack rock formations. The best exposures are found along the principal stream courses, as for example in the vicinity of Enos. Over the Paleozoic area the till varies much in character chiefly according to the kind of underlying rock formation. Where the till rests upon the Utica shale it is always dark colored and full of black shale fragments. Where the limestone is the country rock the till is lighter colored and full of limestone (usually coarse crystalline) fragments. Near the shale contact and for some distance away from it the color and composition of the till is generally intermediate, containing both shale

[1] More recently the writer has observed good striae on the syenite near Hawkinsville, just off the map to the northwest. These striae also bear about s. 30° e.

and limestone. Such till is commonly seen between Remsen, Hinckley, Trenton and Steuben valley. The till is nearly always covered with sand or sand and gravel.

The best single exposure of glacial drift, including till at the bottom, is at the sharp creek bend southwest of Hinckley [*see* pl. 9]. The creek is rapidly cutting into the soft drift material and an excellent section over 200 feet thick is exposed. In the bed of the stream here upper Trenton limestone outcrops. Resting directly upon the limestone is a thin bed (1 or 2 feet thick) of stratified sand clay. Above this comes a bed of bluish gray clay (till) full of glaciated limestone boulders, together with some Adirondack rocks. This bed makes up about ¼ of the total hight of the bank. Then comes a mass of sand crudely stratified and cross-bedded, with some gravel streaks and making up approximately ½ the hight of the bank. The upper ¼ of the section is made up of coarse gravel showing crude stratification and cross-bedding.

Till is also well shown at Remsen, east of Prospect and along the streams, near the shale contact, north and northeast of Steuben Valley.

Kame–morainic deposits

A broad belt of kame material extends across the map from southeast to northwest. The width of this belt is generally several miles and although it varies a good deal, and is of uncertain extent, it is nevertheless a distinct feature of the region. Strictly it must be regarded as a lateral moraine, but for most part it partakes of the nature of a terminal moraine. The continuation of this morainic belt southeastward across the Little Falls district has been described by Cushing.[1] It also continues northwestward across the Port Leyden district as is clearly shown upon the newly published topographic map. Presumably this moraine was formed near the edge of the ice sheet during a pause in its retreat as it was melting and retreating southwestward from the Adirondacks. The character and depth of the deposits argue for a nearly stationary condition of the ice for a considerable length of time. Sometimes the deposits show no signs of stratification but at other times a crude stratification is clearly evident, hence the application of the term "kame-moraine." The stratification indicates deposition in connection with water, probably emerging from along the ice edge, and whose currents were shifting. The familiar "knob and kettle" structure of terminal moraine topography is often locally well de-

[1] *Op. cit.* p. 75.

Plate 9

W. J. Miller, photo.

Section showing the character of the glacial drift ½ mile southwest of Hinckley, where West Canada creek makes a sharp bend. The thickness of the section is about 200 feet. Heavy beds of the upper Trenton are visible at the water level to the left. The lower 50 feet is bluish gray till containing striated limestone boulders; the middle 100 feet is crudely stratified sand; while the upper 50 feet is cross-bedded gravel.

Plate 10

W. J. Miller, photo.

Kame hills of the "kame moraine" 2½ miles east of Remsen. The view was taken from the top of a kame.

veloped. The greatest accumulation of kame-moraine materials (sand and gravel) is in the vicinity of Hinckley and for 5 or 6 miles northward where it forms a ridge rising from 100 to 200 feet above the surrounding country [*see* pl. 10]. Many kame hills and kettle holes (not shown on the map) occur in this locality.

Sand hill at the extreme southeast is another example of the kame-moraine hills. The deposit here consists of sand and gravel, is crudely stratified, and is several hundred feet deep.

Minor kames occur 1 mile east of Bardwell Mill and 2½ miles northwest of Enos, and 2 and 3 miles northeast of Remsen.

A little over a mile south of Forestport there is a group of kame hills in the midst of which lies a " kettle hole," 30 or 40 feet in depth. Three such hills forming a group, 3 miles northeast of Forestport have a deep " kettle hole " between them.

Stratified clay deposits

Thinly stratified or laminated clays have been noted in a number of locations, and they certainly indicate the former presence of lakes. Such clay beds, lying between the 1200 and 1300 foot levels, occur over the whole area between West Canada and Black creeks and to an unknown distance eastward beyond the map limits. These clays also extend a little north of West Canada creek and for a considerable distance south of Black creek. The best exposures may be found along the creek south of Northwood and along Black creek between Grant and Gray. Sand everywhere rests upon the clay above the 1300 foot level. The evidence is conclusive that an extensive body of water once occupied the area here described. The water, in all likelihood was held in by the ice front or morainic deposits or both on the south side and by the high Precambric land on the north side.

Similar clay beds outcrop extensively along Black river between 1 and 2 miles southwest of Enos and again at the small lakes 2 miles east of Bardwell Mill. Between these points clay beds also appear. The exposures all lie between the 1200 and 1260 foot levels and argue for the existence of a lake of considerable size. This water body and the one above described were at approximately the same level and they may have been joined during part or all of their [illegible].

Stratified clays may be seen along West Canada creek south of Trenton Falls at a much lower level (740 feet). This water body was formed at a later time when the ice had retreated farther south.

Another lake in the extreme northwest extending to an unknown

distance beyond the map limits existed at an elevation of from 1100 to 1150 feet. The clay beds are best shown along the canal feeder between 2 and 3 miles northwest of Forestport and also along Crystal creek and Cold brook. These and probably other water bodies were doubtless formed behind the ice front or morainic deposits acting as a dam on the west.

Sand deposits

Extensive deposits of sand, frequently associated with gravel, and more or less distinct from the kame-moraine material, occur within the district. These sand areas, which are locally called "sand flats," for the most part lie east of the Precambric Paleozoic boundary line. Many times these sands show no sign of stratification while at other times a crude stratification can be made out.

The largest sand covered area lies between Alder Creek, Enos and Myers hill and northwestward beyond the limits of the map. Over this whole region occupying about 50 square miles scarcely any rock exposures can be found except along the principal stream bottoms.

Sand flats are also found to the east, southeast and south of Enos. The most interesting sand flat is the one lying between West Canada and Black creeks. The topographic map shows it as a flat topped bench or terrace. The sand is here from 50 to 100 feet deep and is underlain by the extensive clay beds above described. Sand flats at lower levels also occur in the vicinity of Trenton Falls.

The problem of the classification and origin of these sands is a difficult one. It is evident from their varying character and distribution that no single explanation will account for them all. In a general way at least the writer offers the suggestion that the unstratified sands were largely deposited as simple drift or morainic material, while the cruder stratified portions were partly the result of overwash deposits from the edge of the ice and the moraine, and partly delta deposits formed where the larger streams emerged from the high Precambric land to the northwest.

The distribution of the sand flats, their absence from the Precambric highlands, the steep slopes of the stream beds and the presence of much sandy drift over the Precambric highland, and the ice and moraine barrier to the southwest causing the formation of the lakes and acting as a general obstruction to drainage would altogether strongly argue for the delta method of origin of much of the sand. Thus the sand overlying the clay between West Canada

Plate 11

W. J. Miller, photo.

A glacial boulder or erratic in the bed of Black creek, ½ mile northwest of Grant. The rock is syenite and it rests upon Trenton limestone. Limestone layers show at the left. The logs are 13 feet long.

and Black creeks was most likely pushed out over the clay as a delta deposit by the creeks named. The heavy sands around Trenton Falls are thought to be of later origin as delta deposits from West Canada creek when the ice had retreated farther south.

Erratics

The whole region covered by the map is strewn with thousands of glacial boulders or erratics. These erratics are mostly representatives of the Precambric formations, even over the Paleozoic area. They vary in size from those which are very small to others which are 10 or 12 feet across and weigh from 50 to nearly 100 tons apiece. The accompanying photograph [pl. 11] shows a large syenite erratic resting on the Trenton limestone in the bed of Black creek below Grant. Glacial boulders of considerable size are often associated with the kame-moraine deposits as for example north of Hinckley. Over the typical sand flat areas they are generally absent and this is probably due to the deposition of these sands after the retreat of the ice thus causing them to be buried and lost to view except along the stream channels where they have been again exposed by subsequent erosion of the sands. The erratics over the Precambric area cause trouble in mapping because it is often difficult to distinguish between them and true outcrops. In the fields around Remsen and Alder Creek station hundreds of large erratics may be seen.

The distribution of these glacial boulders whose source was in the Adirondacks, over the southwestern portion of the district as for instance over Starr hill and to the west as well as for many miles south of this region indicate that at the hight of glaciation the predominating ice current was southerly rather than southeasterly.

Drainage

For the most part the larger streams such as Black river, West Canada and Black creeks, now occupy the same channels that they did during preglacial times. The most noticeable exception is the course of West Canada creek below Prospect. Between Prospect and Trenton Falls, West Canada creek certainly passes through a postglacial channel as shown by the series of waterfalls and the steep sided gorge. The writer has every reason to agree with Brigham[1] who has discussed the matter and who makes the following tentative statement. " It is held as possible that before glacial

[1] Geol. Soc. Am. Bul. 1898. 9:191.

times its course may have continued to the southwest, past Holland Patent, along Nine Mile Creek valley to the Mohawk, near Oriskany. The evidences are a broad open valley, adequate to the Ohio or Susquehanna, at Holland Patent and Stittville, now occupied by a minor stream; the more normal arrangement of drainage thus postulated; massive barriers of glacial debris north and east of Holland Patent; superior altitude of West Canada creek bottom below Trenton Falls as compared with Holland Patent; a very level stretch of some five miles of the West Canada creek about Poland, and the constriction of the valley about Middleville. The supposition is that morainic obstruction blocked the old channel and sent the creek across a col not far from Middleville."

The course of the preglacial stream between Prospect and Holland Patent is not certainly known but it was probably a short distance south of the fault-fold line judging by the heavy drift deposits and lack of rock exposures there. Above Hinckley, West Canada and Black creeks are in or close to their preglacial channels which have been so thoroughly drift filled that the only rock exposure is at Grant. The small rock channel at Grant probably means that the stream has slightly diverged here.

Black river above Enos is certainly in its old channel while at Enos and for several miles down the stream appears to have abandoned its old course. The rock gorge at Enos is certainly of recent origin. The lower course of the stream upon the map seems to follow the preglacial channel except possibly at Forestport where there may have been a slight divergence. Where the railroad crosses Big Woodhull creek the stream is out of its old course as shown by the steep sided rock channel. Town Line (Cincinnati) creek must occupy a postglacial channel between Remsen and near its mouth, as is particularly well shown by several waterfalls and the small gorge northeast of Trenton village.

ECONOMIC GEOLOGY

Soils

The best soils are found over the Paleozoic rock area, the richest farming section covering the western portions of the towns of Remsen and Trenton and the eastern portion of Steuben. Over the section named the drift is generally shallow and the shale and limestone soils make rich farming lands.

The whole region of the kame-moraines and sand flats is characteristically barren, the soil generally consisting of almost pure loose sand which does not afford proper nourishment for plant life unless

well fertilized. In every case, over this region however, where the clay beds are at or near the surface more fertile spots are to be found. The potato crop seems to be best adapted to these sandy soils. In the region to the north and east of Forestport and of Grant many deserted farms may be seen. Formerly the people who lived in these districts were mostly engaged in the timber business, but since the removal of the timber the soils alone have often been too poor to support the families.

The northwestern Precambric highlands are not so heavily drift covered; deep soils are scarce; and the region is mostly wooded. Where occasional patches of soil can be found they are generally fairly productive.

Building stone

The coarse crystalline limestones of the uppermost Trenton afford the best building stone in the district. This rock occurs in thick beds separated by thin shale partings and hence is easy to quarry. A number of large quarries have been opened along West Canada creek between Prospect and the railroad bridge. Quarries near Prospect are now in operation for the production of building stone. This limestone has also been burnt for lime. The same rock has been quarried along the fold-fault line between Trenton and Holland Patent; north of Steuben Valley and along the creek south of Remsen. The extent of the limestone as a surface rock is given above.

The Lowville limestone outcropping along Black river at the extreme northwest is not worked but it would make an excellent building stone.

Because of the expense involved in quarrying and cutting the Precambric rocks have been very little used for building purposes. The railroad company has quarried the stone at Meekerville and at the point where the railroad crosses Big Woodhull creek, for local use in the bridge abutments.

Road material

An unlimited supply of excellent road material is to be found over the whole Precambric area. Most of these rocks would be very suitable although the pure syenite because of its hardness and resistance to wear is best. The expense in quarrying and the general lack of interest in good roads has prevented its usage to any extent.

A rock which is more easily available and better adapted to the usual kind of road work is the coarse limestone at the top of the

Trenton. This rock is much softer than the syenite although it withstands a reasonable amount of wear. The middle and lower Trenton limestones afford road material of medium quality.

Sand and gravel

Sand and gravel of good quality occur in practically unlimited quantities, especially over the moraine and sand flat belt. The railroad company has removed large quantities from a number of places along their lines. Much sand is being shipped by canal from northwest of Forestport to Syracuse and other interior points to be used for building purposes.

Clay

The clay underlying the sand flat between West Canada and Black creeks is of excellent quality and almost unlimited in quantity. It is very fine grained, free from grit or gravel and would be well suited for the manufacturing of brick, tile etc. The clay beds farther northwest are of similar quality.

Iron ore

In the Precambric area some prospecting for iron ore has been done in at least two localities. One of these is situated about ½ mile south of Ash ridge and on the divide between Hare brook and Big brook while a second place is about ¾ mile north of Enos. The prospects are small pits made largely by blasting. The ore is magnetite which occurs in a coarse grained rock, and associated with feldspar, ranging from oligoclase to labradorite, and a considerable percentage of quartz. The ore-bearing rock is usually associated with a dark gray banded rock in which the dark bands are very biotitic. The best specimens found by the writer did not contain more than 20% of magnetite. Many years ago some ore was shipped out but the quality was found to be too poor. There is nothing to indicate that further prospecting at the places mentioned would bring to light any good ore. Magnetite is a very common constituent of the syenite rocks and at times it appears to be particularly rich in what the writer regards as segregation masses. Small patches of magnetite have been often observed especially in the more syenitic rocks of those mapped as Syenite-Grenville. It should be noted that the Salisbury iron mine a number of miles to the southeast as well as the prospects here described all occur within the Syenite-Grenville areas. Possibly the close association of the syenite and Grenville in some way made the conditions for segregation more favorable.

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New York State Museum

JOHN M. CLARKE, Director

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The divisions to which bulletins belong are as follows:

1 Zoology
2 Botany
3 Economic Geology
4 Mineralogy
5 Entomology
6 "
7 Economic Geology
8 Botany
9 Zoology
10 Economic Geology
11 "
12 "
13 Entomology
14 Geology
15 Economic Geology
16 Archeology
17 Economic Geology
18 Archeology
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25 Botany
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19 Merrill, F. J. H. Guide to the Study of the Geological Collections of the New York State Museum. 164p. 119pl. map. Nov. 1898. *Out of print.*

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48 Woodworth, J. B. Pleistocene Geology of Nassau County and Borough of Queens. 58p. il. 8pl. map. Dec. 1901. 25c.

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106 Fairchild, H. L. Glacial Waters in the Erie Basin. 88p. 14pl. 9 maps. Feb. 1907. *Out of print.*

107 Woodworth, J. B.; Hartnagel, C. A.; Whitlock, H. P.; Hudson, G. H.; Clarke, J. M.; White, David; Berkey, C. P. Geological Papers. 388p. 54pl. map. May 1907. 90c, *cloth.*

Contents: Woodworth, J. B. Postglacial Faults of Eastern New York.
Hartnagel, C. A. Stratigraphic Relations of the Oneida Conglomerate.
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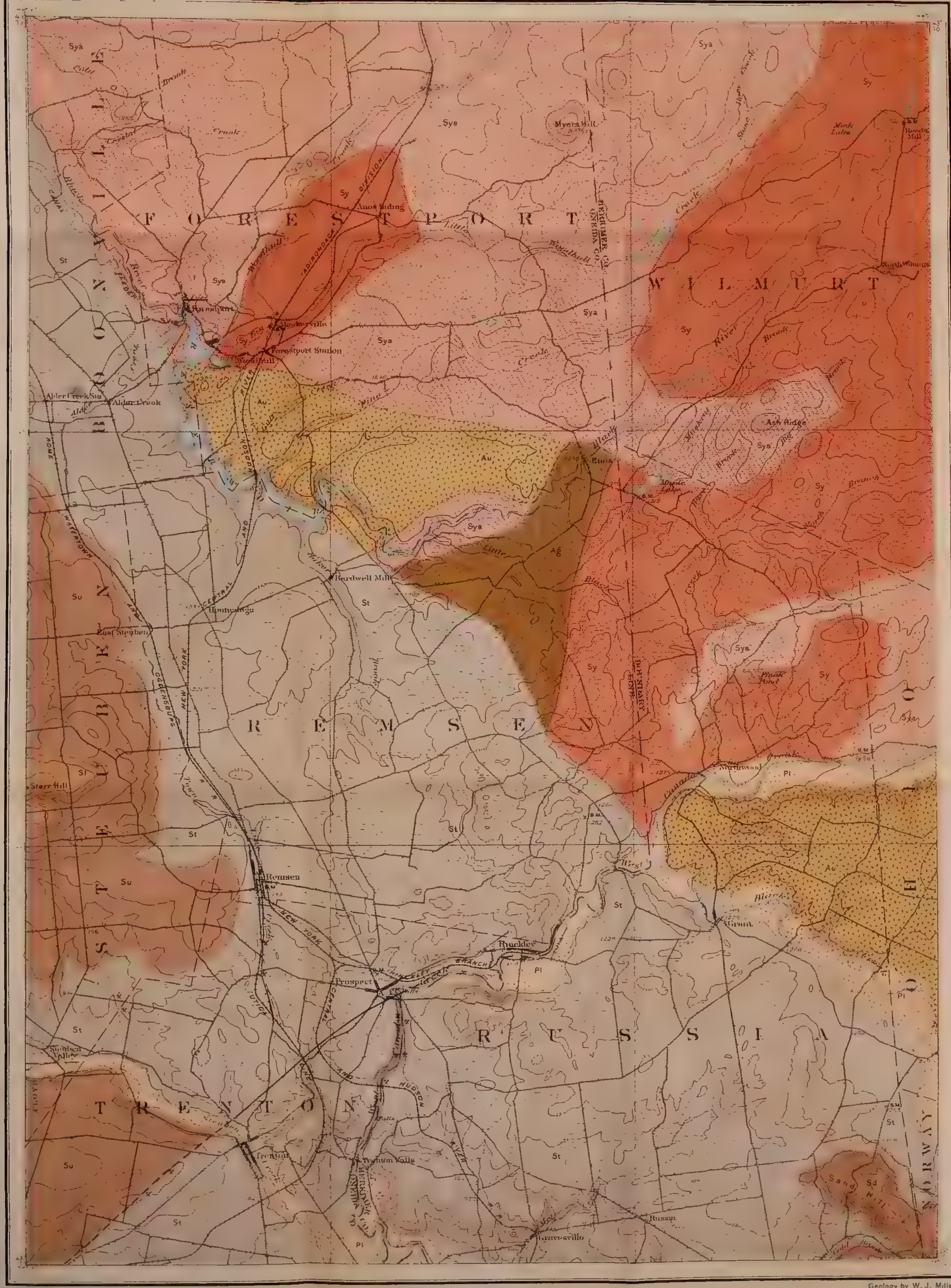

LEGEND

Sedimentary Rocks

PLEISTOCENE

Pl — Modern Valley Alluvium together with more or less reworked Glacial drift.

LOWER SILURIC

St — Lorraine Beds. Gray to black shales containing thin layers of sandstone.

Su — Utica Black Shales. Calcareous in lower portion.

Sd — Dolgeville (upper Trenton) shales. Alternating thin beds of limestone and shale.

St — Trenton Limestone, including the Lowville at the base. Coarse, crystalline, heavy beds at the summit.

Metamorphic Rocks.

PRECAMBRIC

Sy — Syenite. A rather quartzose rock, showing a gneissic structure and of undoubted igneous origin. Younger than the Grenville.

Ag — Grenville Formation. Highly metamorphosed sedimentary rocks, showing a distinct gneissic structure and containing garnet and graphite.

Sya — Syenite-Grenville Complex. Clearly gneissoid rocks of various types, but mostly Grenville much cut up by intrusions of syenite.

Au — Precambric rocks of unknown character because buried under heavy Glacial drift.

Fault

Stone Quarries.

Topography by W.H. Lovell and C.C. Bassett

Geology by W. J. Miller
1907.

Bassett
Lovell

Scale 1:62500

Miles

Kilometers

Contour interval 20 feet

Datum is mean sea level

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